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STUDY OF INTENSITY OF RADIATION EMITTED BY GLOW DISCHARGE

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_**Abstract:**

Phenomenon of DC glow discharge is the most essential part of the electrical and spectral emission studies of the molecules, atoms and ions in the interface of solid and liquid. We measured the intensity of radiation emitted by glow discharge as a function of discharge current for the fifteen aqueous solutions. We tried to analyze the results and tried to obtain the relation between the current passed through the discharge and intensity by the discharge. We develop one empirical equation which explains the intensity emitted by glow discharge which related with volume of the plasma and ionization potential.

Keywords: Glow discharge, interface, intensity, plasma, ionization potential

Introduction

The light plays very important role in several basic and Applied Physics laboratories. Tunable light source is needed in the study of the branches of spectrometry like light induced fluorescence spectroscopy, synchronous luminescence, absorption spectroscopy, higher resolution spectroscopy [1] etc. The light source emitting the radiation in the range 200 nm to 1100 nm is provided by the sources like deuterium lamp [2] and halogen lamp. In fact the light radiation at wavelength shorter than 200 nm and longer than 1100 nm are also needed. The tunable radiation having above mentioned wavelengths may be obtained by some other technique.

The Fourier transform spectroscopy needs the tunable radiations in the infrared region of the electromagnetic wave spectrum. The radiation in this range may be provided by infrared lamps working on the principle of black body in thermal equilibrium. The tunable radiation in soft X-ray region is required for the study of X-ray fluorescence, which has wide application in medical science [3,4].

Many monochromatic sources of light are required in the field of study of interferometer of extreme ultraviolet lithography optics [5], holography [6] etc. The lasers [7] play very important role in the fields like interferometry and holography [8] as they have very narrow bandwidths. The lasers have found the applications in several areas of science. The work in the area of nonlinear effect, frequency doubling field, doppler free spectroscopy and the radiation cooling is not possible without laser.

The glow discharges provide the source of moderately monochromatic light. This light may be utilized for the production of fringes using Michelson interferometer. The Newton's rings also may be generated by using the glow discharge source. The phenomenon like coherence length [9] of the light source may also be studied by investigating the interference pattern and Fourier transform of the radiation. In order to study the applications of the light sources the properties of the light sources must be studied in detail.

Electromagnetic Nature of Light

The light emitted by any source is electromagnetic in nature. An electric field and magnetic field are associated with the light waves. The electric and magnetic field vectors are perpendicular to each other and both are perpendicular to the direction of propagation. In 1845 the master experimentalist Michael Faraday (1791-1867) established an interrelationship between electromagnetism and light when he found that the polarization direction of a beam could be altered by a strong magnetic field applied to the medium. The propagation of light is fully governed by the Maxwell's equations. James Clerk Maxwell (1831-1879) brilliantly summarized and extended all the empirical knowledge on the subject in a single set of mathematical equations. The work of Maxwell and subsequent developments since the late 1800s have made it evident that light is most certainly electromagnetic in nature.

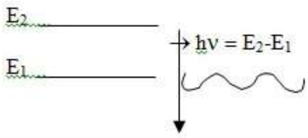
The electromagnetic radiations of light waves have found tremendous applications [10] and therefore the new sources of light having specific properties are very much needed. All the Stars in all the galaxies emit light radiation and the analysis of the light gives more details about the Stars. The emission of the Stars is governed by Planck's radiation law, which may be explained as follows

$$I_{\lambda} = \frac{2\pi h c^{2}}{\lambda^{5}} \left[\frac{1}{e^{hc/\lambda kt} - 1} \right]$$

Where
h is the Planck's constant
k is Boltzmann's constant
λ is wavelength of radiation
c is the speed of light

The spectrum emitted by the stars is continuous spectrum. Similarly spectrum emitted by the halogen lamp, deuterium lamp and incandescent lamp [11] are also continuous and their emission is governed by Planck's radiation law.

The free atoms emit line spectra and spectrum is completely discrete. The typical example of the transition of atom is shown in the following figure.



Light emitting system may have several energy levels but only two energy levels are shown in the figure. When the atom makes transition from upper level E_2 to lower level E_1 it emits a photon of frequency given by $\nu = (E_2 - E_1)/h$. The width of the spectrum line is decided by the temperature of the source. The width of the spectrum line is determined by Doppler's shift arising because of atoms moving with high velocity. Further, the width of the spectrum line is determined by fluorescence lifetime of upper and lower energy levels involved in the transition. In almost all cases the atomic spectrum is discrete containing several spectrum lines having different bandwidths.

The spectra emitted by molecules are entirely different than the spectra emitted by atoms. The spectrum emitted by molecular medium is determined by the electronic energy, vibrational energy, rotational energy and velocity of the molecules. The total energy of a molecule has four components and therefore spectrums emitted by the molecules are relatively complicated. In case of polyatomic molecules the spectra emitted by the media contains bands of the radiation.

The intensity of the light emitted by the source of continuous spectrum is determined by its temperature [12]. At the micro level we can say that the intensity emitted by the source is decided by number of particles in excited state and transition probability of the transition which gives rise the emission of a photon. The total intensity emitted by source of light is sum of intensities at all the wavelengths of emission.

Materials and Method:

Spectral study of the glow discharge [1-7] of the material helps in studying the chemical composition of the material. Under this spectrochemical study the elements in the material may be excited in the plasma [8,13] produced between solid and liquid interface. The solid liquid junction is formed when current is passed through the junction; a plasma film is generated along the interfaces between solid and liquid. The plasma pressure is very near to the atmospheric pressure [9]. The plasma parameters in DC glow discharge may be generated by a current source [10,13]. The used method is very low cost and quick results may be obtained and therefore has wide applications.

With this background of glow discharge, an attempt has been made to develop a new type of glow discharge system for the purpose of doing the analysis in the interface of solid and liquid in which liquid acts as one of the electrodes and tungsten acts as a another electrode. The new system requires very less amount of electrolytic solution. A plasma film is generated along the interfaces between tungsten and liquid. The knowledge gained from fundamental studies has the potential to further improve the spectrochemical performance as earlier studies have. The work presented here characterizes characteristics of the plasma generated between tungsten electrode and the liquid along with the study of V-I characteristics of about 15 different electrolytic solutions by applying different polarities to liquid and solid which form the interface, measured the change in intensity of radiation emitted by glow discharge as a function of discharge current.

Result and Discussion:

We measure the intensity of radiation emitted by glow discharge as a function of discharge current for the aqueous solutions $Cd(NO_3)_2$, $LiNO_3$, $Pb(NO_3)_2$, TiO_2, $Bi(NO_3)_3$, $ZrOCl_2$, $FeSO_4$, $NiSO_4$, SeO_2, $CuSO_4$, $COCl_2$, $AgNO_3$, $CaCl_2$, $BaCl_2$ and $MgSO_4$ as anode. The few results are displayed in the figures 1 through 9. The discharge current is plotted along X-axis and logarithm of intensity along Y-axis. The results obtained shows very interesting features. Out of 9 displays, 8 displays show that the experimental curves in the figures is a combination of two straight lines and 9^{th} figure for aqueous solution of $MgSO_4$ shows that the curve is a combination of three straight lines.

We obtained the slopes of the straight lines and tabulated in table 1. The table 1 also shows the ionization potentials of the corresponding ionic species.

We tried to analyze the results and tried to obtain the relation between the current passed through the discharge and intensity emitted by the discharge. We develop many empirical equations for explaining the intensity emitted by the glow discharge. After considering ten to fifteen expressions it found that one equation is very much useful. The most interesting equation developed by us may be written as

$$I = A e^{BD/C}$$

Where

I is intensity emitted by glow discharge

A, B and C are constants

D is discharge current

All the curves are fully explained by the equation given above. It is obvious that if the discharge current is increased, the energy deposited into plasma increases and consequently more heating of ions and electrons take place and the ion and electron temperature also increase. The increase in electron temperature may increase the rate of production of active ion, rate of excitation of the energy levels of the active particles. The constant C in the equation is nothing but the ionization potential of active ion. The factor A may be treated as a constant which is determined by factors like volume of the plasma, the distance between glow discharge and detector, container of the solutions, the number of electrons in outermost orbit of the active particle etc. The factor B is determined by dissociation partner of the active ion.

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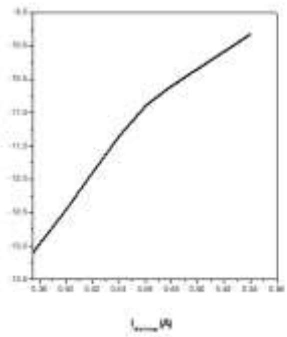

Fig.1: Intensity of radiation emitted by glow discharge as a function of discharge current for aqueous solution of 0.5N $Cd(NO_3)_2.4H_2O$

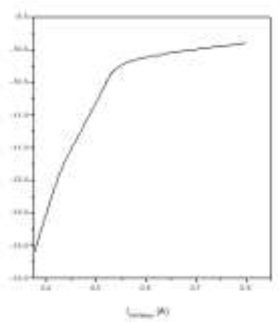

Fig. 2: Intensity of radiation emitted by glow discharge as a function of discharge current for aqueous solution of 0.25N $LiNO_3$

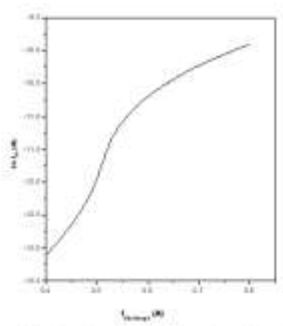

Fig.3: Intensity of radiation emitted by glow discharge as a function of discharge current for aqueous solution of 0.1N $Pb(NO_3)_2$

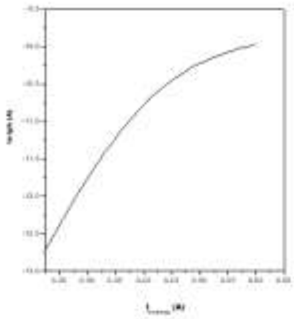

Fig.4: Intensity of radiation emitted by glow discharge as a function of discharge current for aqueous solution of 0.25N TiO_2

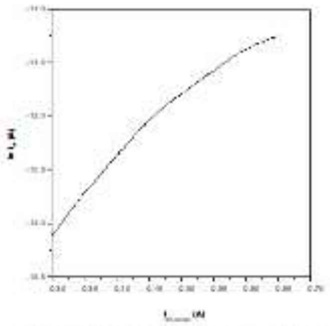

Fig.5: Intensity of radiation emitted by glow discharge as a function of discharge current for aqueous solution of 0.5N $Bi(NO_3)_3.5H_2O$

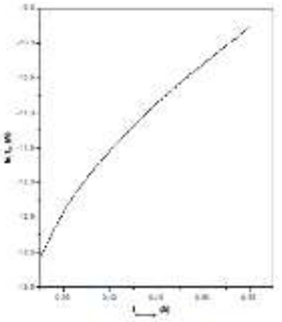

Fig.6: Intensity of radiation emitted by glow discharge as a function of discharge current for aqueous solution of 0.25N $ZrOCl_2.8H_2O$

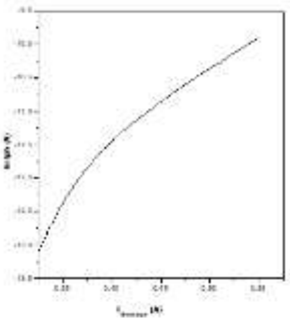

Fig.7: Intensity of radiation emitted by glow discharge as a function of discharge current for aqueous solution of 0.1N $FeSO_4$

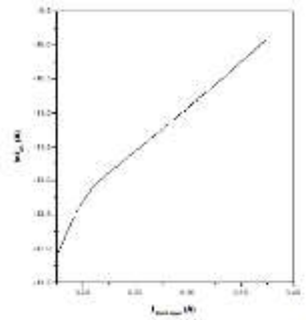

Fig.8: Intensity of radiation emitted by glow discharge as a function of discharge current for aqueous solution of 0.5N $NiSO_4$

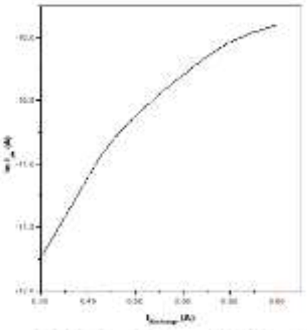

Fig.9: Intensity of radiation emitted by glow discharge as a function of discharge current for aqueous solution of 0.5N $MgSO_4$

Table 1: Slopes of the straight lines along with the ionization potentials of the corresponding ionic species

Sr.No.	Electrolytic solution	I.P.I eV	I.P.II eV	I.P.III	Slope I	Slope II	Slope III
1	0.5N Cd(NO3)2.4H2O	8.99	16.904	37.47	25	12.14	
2	0.25N LiNO3	5.39	75.62	122.419	20	0.96	
3	0.1N Pb(NO3)2	7.415	15.028	31.93	10.58	3.67	
4	0.25N TiO2	6.83	13.63	28.14	12.73	2.263	
5	0.5N Bi(NO3)3.5H2O	7.287	16.68	25.56	7.65	2.7	
6	0.25N ZrOCl2.8H2O	6.95	14.03	24.8	25.99	11.51	
7	0.1N FeSO4	7.9	16.18	30.64	22.857	9.42	
8	0.5N NiSO4	7.633	18.15	36.16	34	12.5	
9	0.25N SeO2	9.75	21.5	32	19	9.6	
10	0.5N CuSO4	7.724	20.29	36.83	21.31	7.1	
11	0.25N COCl2	7.86	17.05	33.49	14.33	6.172	
12	0.05N AgNO3	7.574	21.48	34.82	17.26	5.95	
13	0.5N CaCl2	6.111	11.87	51.21	10.11	5.02	

14	0.5N $BaCl_2$	5.21	10.001	17	14.5	6.2	
15	0.5N $MgSO_4$	7.644	15.03	80.12	12.897	6.2288	2.1